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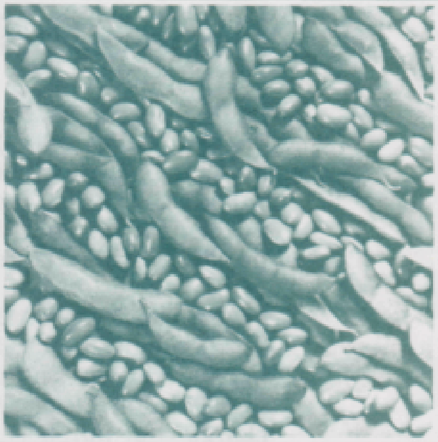
Potential Bans of Corn and Soybean Pesticides

Economic Implications For Farmers and Consumers

Craig Osteen and Fred Kuchler



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Abstract

Removing corn and soybean pesticides with alleged environmental and safety risks from the market could increase U.S. agricultural production costs, crop prices, farm incomes, and consumer expenditures, causing farmers to gain and consumers to lose. Banning all triazines, acetanilides, soil insecticides, or seed treatments would have the largest effects. This report uses an econometric-simulation model, incorporating relatively new developments in welfare economics, to analyze the economic implications of potential bans of corn and soybean insecticides, nematicides, fungicides, and herbicides through cost and yield assessments. Banning an individual corn or soybean pesticide would not significantly affect crop production, but banning all pesticides used for an important pest problem would have substantial effects. This study also demonstrates the interdependence among pesticide regulatory decisions.

Keywords: Pesticide regulations, benefit-risk assessment, economic implications, corn, soybeans, pesticide use

Note: The use of company trade names is for descriptive purposes only and does not imply endorsement by the U.S. Department of Agriculture.

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Summary

Removing corn and soybean pesticides with alleged environmental and safety risks from the market could increase U.S. agricultural production costs, crop prices, farm incomes, and consumer expenditures, causing farmers to gain and consumers to lose. Banning all triazines, acetanilides, soil insecticides, or seed treatments would have the greatest effects. Farmers would gain in the aggregate from lowered yields because fewer crops would enter the market, causing prices, and thus incomes, to increase.

This report examines the economic implications of potential bans on corn and soybean insecticides, nematicides, fungicides, and herbicides from the marketplace. Economic implications include losses in yield potential, changes in U.S. production and production costs, input price increases, crop price increases, and changes in profits. TECHSIM, an econometric-simulation model incorporating relatively new developments in welfare economics, uses data representing technological or regulatory changes (per-acre cost and yield changes), estimates changes in economic welfare, and forecasts changes in per-acre and total profits for each of the 13 domestic production regions examined.

Of all the scenarios examined, banning triazines (atrazine, cyanazine, metribuzin, and simazine), acetanilides (alachlor and metolachlor), all soil insecticides (carbofuran, chlorpyrifos, disulfoton, ethoprop, fonofos, isofenfos, phorate, terbufos, and others), or all seed treatments (captan, carboxin, and thiram) would have the largest effects on U.S. crop production. Banning all foliar insecticides, thiocarbamates, or dinitroanilines would cause only minor effects. Except for atrazine and bentazon, banning the individual compounds (or a few insecticides) examined would have only minor effects. However, individual growers in some regions could suffer substantial losses.

Other findings in this report include:

- If any corn or soybean pesticides were removed from the market, production efficiency would decline from lower yields and higher production costs, causing higher prices. Therefore, producers would gain from higher prices but consumers would bear a substantial cost of the removal.
- In all scenarios, the prices of corn and soybeans would increase while production would decrease, regardless of whether one or both crops were directly affected by the potential ban. The returns to crops treated with regulated pesticides would almost always increase more than would the returns to other crops. However, farmers suffering increased crop losses due to the removal of a pesticide may suffer financial losses even though farmers as a whole would gain.
- Overall effects of the pesticide removal would be relatively small if individual compounds (except for atrazine or bentazon) were withdrawn but much greater if entire pesticide groups or all alternatives for a pest problem were withdrawn.
- Canceling a pesticide registration reduces the number of alternatives available for a particular pest problem and thus the number of alternatives available in the event of any future cancellation. Economy-wide impacts could occur if enough pesticides were removed from the market and if new alternatives were not introduced. This problem is compounded if a pesticide examined later is found to have greater health, safety, or environmental risks than a pesticide previously removed from the market.

Potential Bans of Corn and Soybean Pesticides: Economic Implications for Farmers and Consumers

By Craig Osteen and Fred Kuchler

Introduction

Pesticides prevent losses in crop yields caused by insects, diseases, nematodes, and weeds. However, pesticide use may create environmental and safety risks. The U.S. Environmental Protection Agency (EPA) examines the risks of pesticides, weighs those risks against the benefits, and decides whether any pesticide should be removed from the market. Removing agricultural pesticides from the market may reduce the efficiency of crop production: yields may decrease due to pest infestations, or the costs of production may increase, which could increase costs per unit of output. If crop losses and/or cost increases are great enough and are suffered over a large area, repercussions would occur throughout the economy. Aggregate production would decrease and crop prices would increase, so consumers would bear a substantial portion of the costs of pesticide regulations.

This report estimates the aggregate economic effects of potential bans on corn and soybean pesticides, including changes in crop production, crop prices, farm incomes, and the sum of consumer welfare and intermediate profits. Analysis of regional effects or redistribution of income among different groups of farmers will be left to other reports. No attempt was made to compare risks and benefits or to consider potential long-term effects of regulations on pest resistance to pesticides, changes in pest composition, new pest control developments, or the viability of individual farms.

Expert estimates of yield losses and changes in production practices resulting from a variety of pesticide bans can be found in (*10-15*).[1] This report demonstrates the economic implications of some of those estimates and reveals an interdependence among regulatory decisions. Removal of a pesticide from the market reduces the number of alternatives available for future consideration. And although the effects of removing a pesticide from the market may be minor, removal may increase the economic effects of future decisions to remove other pesticides from the market. The current regulatory process does not account for this interdependence and could result in substantially harsher economic effects over time than would an approach which accounts for the interdependence. This report, and the pesticide assessments upon which it is based, suggests ways to account for this interdependence in the pesticide regulatory process.

Several corn and soybean pesticides are currently under EPA regulatory review and could have their registrations modified or canceled: captan, a seed treatment for corn and soybeans; alachlor and linuron, corn and soybean herbicides; cyanazine, another corn herbicide; and aldicarb, a soybean insecticide/nematicide. EPA wants data on many corn and soybean pesticides as part of reassessment and reregistration.

Note: The results presented in this report are preliminary and should not be construed as an official U.S. Department of Agriculture response to EPA regulatory actions.

[1]Italicized numbers in parentheses cite sources listed in the References.

Pesticide Regulations and the Agricultural Economy

Removing pesticides from the market reduces options available to control some pests. Alternative controls, if any, may be less effective in reducing pest populations and preventing pest damage to crops. Yields may decrease and/or production costs may increase. Even if equally effective alternative controls were available, they may be more expensive. Also, farmers may try to maintain yields by using cultural practices, such as cultivation, which increase costs. Yield losses and cost increases will reduce production efficiency for farmers directly affected by pesticide bans.

If the pesticide(s) withdrawn from the market was popular and could be used to control more than one pest, the demand for alternative pesticides might increase enough to increase pesticide prices. Prices could remain high until production capacity or supplies of materials increase. If there were few alternative pest controls, banning one or more pesticides could give sellers market power and they, in turn, could maintain higher prices for alternative pesticides. However, pesticide price increases will not only affect costs for farmers who purchased the banned pesticide but also for all farmers who use alternative pesticides.

If substantial yield decreases or cost increases are suffered over a large area, the market will spread the effects on production efficiency unevenly throughout the economy, changing the prices and production of several crops. Higher costs or reduced profitability from lower yields will induce some farmers to grow other crops (requiring a different pesticide mix) or to abandon farming. The supply shift would lead to higher commodity prices, which in turn influence planting decisions, and lead to acreage changes for crops directly affected by the pesticide ban and for crops that farmers might plant instead. The responsiveness of planted acreage and production to crop price changes is an important factor in distributing the effects of regulations. The efficiency loss will hurt some farmers, while others will enjoy the resulting price increase. Removing pesticides from the market may increase costs and reduce production possibilities in many sectors. And consumers would bear some of these costs when paying higher prices for food.

Previous Analyses

Previous studies of potential pesticide regulations confronted a scarcity of information about pest losses and farm production cost changes, and the choice of analytical methods. These studies generally relied on expert assessments of yield and cost effects of potential actions. EPA and the U.S. Department of Agriculture (USDA) have conducted short-term assessments of pesticides under regulatory review. Estimates of yield losses and cost changes typically have been developed on a case-by-case basis. Assessment teams developed expert estimates for the pesticide in question.

Early studies analyzed the economic effects through partial budgeting techniques and price elasticities. These studies usually estimated changes in production, production costs, prices, and incomes for the crop directly affected by the regulation under review. These studies did not estimate the response of crops indirectly affected by the regulation or effects on purchasers of agricultural commodities. Attempts to increase the sophistication of the economic analyses of pesticide regulations by computing price and production changes with large-scale models showed interactions between the supply and demand of several crops and also estimated changes in such welfare indicators as producers' and consumers' surplus. Consumers' surplus is the difference between what consumers are willing to pay and what they have to pay to acquire commodities. Producers' surplus measures rents and profits.

EPA has made more recent assessments with TECHSIM, the econometric-simulation model used in this study. A detailed discussion of the methods and issues of four studies follow: two studies are early assessment studies for aldrin and trifluralin and two are academic studies incorporating more sophisticated economic analyses.

Delvo analyzed the economic effects of canceling the registration of aldrin, an organochlorine insecticide used on corn to control wireworms and cutworms, before its registration was canceled in 1975 (*5, 21*). State crop experts estimated the State-level effects on yield of the cancellation and of alternative insecticide use. Delvo used partial budgeting to estimate cost changes and used a price elasticity estimate from another study to estimate the price changes from lower corn production. Assuming acreage was constant under the set-aside program, Delvo analyzed cases where alternative pesticides were used and where they were not. In both cases, variable costs increased, production decreased, and prices increased. When alternative insecticides were used, corn prices increased less than 1 percent, the income of all corn producers increased, but the incomes of aldrin users decreased. When alternatives were not used, production losses and price increases were greater, and the income of all corn producers, including aldrin users, increased. In both cases, Delvo found that consumers suffered from higher prices and lower production, but no measure of consumer loss was estimated. Assuming land was brought into corn production to keep production and prices constant, Delvo found that estimated farm income decreased.

Trifluralin is a preemergence, dinitroaniline herbicide used on a wide variety of crops such as soybeans, cotton, and vegetables (*20*). Regulatory review of trifluralin did not lead to its cancellation. The soybean assessment used similar methods to obtain yield and cost information and similar analytical methods as in the aldrin study. A longrun scenario assumed that there would be ample supplies of alternative herbicides for trifluralin-treated acreage. A shortrun scenario assumed that some acreage might not be treated because of shortages of alternative pesticides, even though pesticide prices were assumed constant. The shortrun estimated soybean price increased by $1.35 per bushel to $6.99 and the shortrun corn price decreased by $0.25 per bushel to $2.43. Soybean producers' income decreased but it increased for those not using trifluralin. Longrun soybean production losses and price increases were less than those in the short run. The estimated soybean price increased by $0.43 per bushel and corn decreased by $0.02 per bushel. As a result, the overall effects on agriculture and consumer expenditures were less.

Taylor and Frohberg used a linear programming model of the Corn Belt, including demand functions, to compute price changes and other effects of banning insecticides or herbicides on corn and soybeans in the Corn Belt (*18*). The model simulated the operation of a competitive market by maximizing consumers' plus producers' surplus. For the herbicide ban, corn yields were assumed to decrease by 19 percent and soybean yields by 22 percent (these estimates were based on long-term field plot research and were extrapolated to the entire Corn Belt). Two additional cultivations were also assumed. Simulated results showed that corn prices increased by $0.54 per bushel to $3.00, and soybean prices increased by $1.32 per bushel to $6.58. As a result, consumers' surplus decreased by $3.5 billion and producers' surplus increased by $1.8 billion. The insecticide ban primarily increased corn yield losses from corn rootworm larvae. Loss estimates varied by region and crop rotation. Results of banning insecticides resembled the pattern of banning herbicides but were smaller in magnitude.

Burton examined several herbicide regulatory scenarios using a mathematical programming model that included price-responsive domestic, export, and stock demand equations as well as regional land and labor supply equations (*2*). The model maximized consumers' plus producers' surplus from all marketed commodities. Weed scientists in the major producing States provided the yield loss estimates and identified weed control alternatives for each scenario. Burton examined bans on trifluralin; dinitroanilines; atrazine; triazines; phenoxys, dinitroanilines, and thiocarbamates; and all herbicides. He concluded that if alternatives were available and shifts in cropping patterns were possible, herbicide bans would not significantly affect U.S. agriculture even if several herbicide classes were restricted. However, large regional shifts in production could occur. Burton also concluded that the effects would be more severe if all herbicides were banned: most crop prices increased 10 to 16 percent, production decreased, and regional cash rents increased 16 to 66 percent. Producers gained and consumers lost.

Analytic Methods and Information

This report uses an econometric-simulation model to analyze the effects of potential bans on corn and soybean insecticides, nematicides, fungicides, and herbicides. This report analyzes the information from the *Pesticide Assessment of Field Corn and Soybeans*, assembled under the National Agricultural Pesticide Impact Assessment Program (NAPIAP).

The Pesticide Assessment of Field Corn and Soybeans

This prototype assessment departs from the traditional pesticide-by-pesticide approach used in regulatory analyses in that it considered the interdependence among pesticide regulatory decisions (*10-15*). Only Burton used a comparable information base (*2*). However, the *Pesticide Assessment of Field Corn and Soybeans* includes insecticides, fungicides, and herbicides and considers variations in pest problems and pest control practices by State. Personal enumeration used to assemble the information base also ensured a higher response rate than that achieved by Burton.

The pesticide assessments systematically review major pests; regional variation in pest problems, pesticide use, and pest management practices; and pesticide efficacies of yield. Research and extension experts in major corn and soybean producing States estimated yield losses and identified control alternatives assuming that important registered pesticides and combinations of pesticides were removed from the market. The assessment focused on insect, nematode, disease, and weed problems in 28 States, accounting for 97 percent of the corn and 98 percent of the soybean production during 1978-82.

The estimates were based on survey data, experimental and field research trials, and field experience. Results were recorded on a questionnaire designed to minimize overstatement of pesticide productivity and of effects of pesticide regulations (*17*). The reliance on expert opinion reflects the time and high cost required for sufficient experimental data on climatic, soil, and other factors that determine the extent and the severity of current losses from pests and changes caused by withdrawing major pesticides from the market.

Analytical Model

TECHSIM, an analytical model, estimates changes in crop prices, production, and acreages and computes such welfare indicators as changes in crop rents and economic surpluses. The model considers interactions between supply and demand for major crops and contains many of the same concepts as those used by Burton and by Taylor and Frohberg (*2, 18*).

TECHSIM uses data representing technological or regulatory changes (per-acre cost and yield changes) and estimates changes in economic welfare for major segments of the agricultural economy (*4*). TECHSIM is a regional econometric-simulation model for the U.S. production and distribution of soybeans, corn, grain sorghum, wheat, barley, oats, cotton lint, and cottonseed. The model, which also includes the meal and oil products of cottonseed and soybeans, forecasts changes in per-acre and total profits for each of the modeled commodities in 13 domestic subregions for any number of years (table 1). More highly aggregated welfare changes are forecasted. Welfare changes include the net effect; the total profit changes for producers of each crop and all crops; the total profit changes for producers of meals and oils; and the sum of changes in consumers' surplus and profits for all producers involved in transforming raw agricultural commodities into final consumable products.

Modeling commodity markets helped estimate welfare changes. Estimated supply and demand functions for the commodities are linked in a recursive adjustment model. Annual production of each commodity is based on relative expected profitability of each commodity. Thus, farm-level decisions to maximize profits drive the model. When the cost of production or per-acre productivity of a crop is altered, the expected profitability of that crop relative to all others is altered, thereby inducing shifts in acres planted and production. The model is recursive in the sense that farm profits earned in one simulated year determine planting decisions in the next year.

The model operates through classes of equations. Acreage response functions are based on relative net returns, estimated for each commodity in each region where the crop is grown. Multiplying these functions by the associated per-acre production functions, summing across regions, and then adding inventories, yields the annual quantities supplied. Demands for each commodity consist of several components: feed, food, seed, mill, inventory, and export. Each component, estimated at the national level, is a function of its own and substitute prices. Equating supply with summed demand responses yields excess demand equations for each crop. Simultaneously solving the excess demand equations determines market prices and utilization patterns for the commodities. Prices, quantities, and costs of production allow calculation of regional crop-specific profit levels. Profits supply the links between simulated marketing years. Actual net returns are used as farmer expectations for net returns during the following year. This drives the acreage response functions by altering planted acreage the following year.

The model runs twice: first simulating operation of the commodity markets without the pesticide ban and then simulating the markets with the ban. These runs produce changes in prices, quantities, and acreage measures. Changes in farm income, its distribution,

Table 1 — TECHSIM production regions

Region	States
Appalachia	Kentucky, North Carolina, Tennessee, Virginia, West Virginia
Central Plains	Kansas, Nebraska
Corn Belt	Illinois, Indiana, Iowa, Missouri, Ohio
Delta	Arkansas, Louisiana, Mississippi
Lake States	Michigan, Minnesota, Wisconsin
Northeast	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
Northern Plains	North Dakota, South Dakota
Mountain States	Colorado, Idaho, Montana, Nevada, Utah, Wyoming
Pacific Northwest	Oregon, Washington
Southeast	Alabama, Florida, Georgia, South Carolina
Southern Plains	Oklahoma, Texas
Southwest	Arizona, New Mexico
West Coast	California

the welfare of some direct purchasers of agricultural commodities, and the welfare of consumers and food processors are then calculated. However, TECHSIM does not account for farm programs that may influence crop prices and production, such as price supports, target prices, and production control programs. The model excludes the accumulated inventories under price-support programs during the early eighties.

TECHSIM incorporates relatively new developments in welfare economics. Just and Hueth argued that when the Government imposes a price on a market, prices and profits are affected throughout the marketing chain (*9*). They showed consumers' and producers' surplus could be measured even in long, complex marketing chains. In vertically related industries, where the output of each industry is an input for the industry one step up the marketing chain, the welfare effects of an imposed price distortion in an initial or intermediate market on all forward industries (industries up the marketing chain) can be captured by measuring the change in consumers' surplus. That is, if a calculation to compute changes in consumers' surplus were carried out on an initial or intermediate-level general equilibrium demand function, the change should be interpreted as the change in final consumers' surplus plus the changes in all forward industry rents. Chavas and Collins generalized this analysis to include technological change or distortion (*3*). These ideas were incorporated in the TECHSIM calculations of all rents not at the farm level.

Scenarios and Estimates

Scenarios for insects, nematodes, and diseases were based on pest groups and methods of application: soil insecticides on corn, foliar insecticides on soybeans, nematicides on corn and soybeans, seed treatments on corn and soybeans, and foliar fungicides on soybeans. Scenarios were also developed for major herbicide groups: acetanilides, dinitroanilines, thiocarbamates, triazines, and postemergence herbicides. One, two, or a few chemicals, and then all pesticides used for a target pest or in an herbicide group were assumed to be removed from the market. Some scenarios assumed that, due to scarcity, farmers bid up the prices of alternative pesticides by 25 percent. The estimate of 25 percent was not based on an empirical observation but was chosen arbitrarily to show the results of pesticide price increases. The scenarios implicitly assumed enough time for ample quantities of alternative pesticides to be made available but not enough time for new pesticides to be developed.

TECHSIM uses estimated cost and percentage yield changes averaged over all acreage of the affected crop, not just the acreage treated with the pesticide(s) studied. The *Pesticide Assessment of Field Corn and Soybeans* provided estimates of yield loss averaged over all acreage (as needed by TECHSIM) and information to estimate the cost changes. Average cost changes were computed for the acreage treated with the pesticide(s), including the difference in cost between the regulated pesticide(s) and the alternative compounds plus the cost of additional cultural practices. This average cost change was then multiplied by the proportion of acreage treated with the regulated pesticide(s) to obtain the average cost change over all crop acreage. Estimates of acreages treated and changes in control practices were also obtained from the pesticide assessment. We used retail list prices as the prices of pesticides (*1*). State recommendations and pesticide surveys yielded the application rates (*7, 8, 19*).

Two types of information are presented to summarize the economic effects of different pesticide regulations. Welfare indicators are dollar measures of gains or losses accruing in subsectors of the agricultural economy. These measures include total crop rent, consumers' surplus and forward industry rents, and net effect. Economic variables are presented as changes from simulated base levels and include corn and soybean prices, production, and per-acre returns. The following welfare measures and economic variables are presented for each scenario analyzed:

- **Total crop rent** — The sum of changes in returns to all crops resulting from the imposed cost changes or decreases in productivity.

- **Consumers' surplus** — The sum of changes in forward industry rents and profits plus the change in consumers' surplus for consumers purchasing final products made from these crops. A negative consumers' surplus indicates losses — consumers and the food processing, transportation, and marketing industries paid more for less.

- **Net effect** — The sum of changes in total crop rent, meal and oil rents, and consumers' surplus and forward industry rents. This variable does not measure social welfare changes. A decrease in this variable shows that agricultural production possibilities have been reduced, and that those who gain from a regulation (excluding gains from reduced environmental and safety risks) have not gained so much that they could compensate the losers.

- **Prices of corn and soybeans** — The changes in price levels for each crop, measured in dollars per bushel.

- **Acreage planted to corn and soybeans** — The change in acreage planted to each crop.

- **Production of corn and soybeans** — The percentage change in production.

- **Annual returns per acre for corn and soybeans** — The change in annual returns per acre for each crop, measured in dollars.

The changes in all these measures are presented for model years 1 and 5 after the regulation mandating the removal of the pesticide, except for planted acreage which is presented for years 2 and 5. The modeled changes in these measures typically oscillated each year and settled to an equilibrium in about 5 model years. This report presents the first- and fifth-year results to show the initial and equilibrium changes from the base run. Planted acreage never changes in the first year, so the second year change is presented as the initial change. The fifth-year estimate should be viewed as an indicator of a new equilibrium value, not necessarily as a value after 5 years. TECHSIM has many characteristics of a cobweb model which may forecast greater oscillations of price and production, resulting in a longer time for markets to reach equilibrium than would really occur. The base run estimates for production, prices, and acreage are displayed in table 2. Although price supports were not included in the model, the baseline prices exceeded the support level. So, price changes were not overestimated because the initial price was less than the support level.

Table 2 — TECHSIM base simulation

Indicator	Estimate
Production:	*Million bushels*
Corn —	
Year 1	6,147.67
Year 5	6,174.16
Soybeans —	
Year 1	1,557.91
Year 5	1,562.21
Acreage:	*Million acres*
Corn —	
Year 2	67.71
Year 5	67.93
Soybeans —	
Year 2	57.74
Year 5	57.73
Price:	*Dollars per bushel*
Corn —	
Year 1	2.76
Year 5	2.69
Soybeans —	
Year 1	6.88
Year 5	6.74

Insecticides and Nematicides

Soil insecticides are the most widely used insecticides on corn. Roughly 35 to 40 percent of the U.S. corn acreage is treated annually with such soil insecticides as carbofuran, chlorpyrifos, disulfoton, ethoprop, fonofos, isofenfos, phorate, and terbufos. Corn rootworm larvae and other members of the soil complex are primary targets for these insecticides. Terminating soil insecticide treatments could reduce U.S. corn yields an average of 9 percent, more than the potential losses caused by terminating the treatment of any other corn insect (*16*). Some of the chemicals used as soil insecticides are used to control cutworms (chlorpyrifos) and European cornborers (carbofuran, fonofos) on corn, Mexican bean beetles on soybeans (carbofuran), and nematodes on both corn and soybeans (carbofuran, terbufos).

Foliar applications are the major soybean insecticide treatments. Roughly 2 to 5 percent of the U.S. soybean acreage receives a foliar application each year. The treated acreage is heavily concentrated in Appalachia, the Delta, and Southeast (see table 1 for regional and State delineations). If foliar insecticides were removed from the market, corn earworms could cause 3-percent losses in soybean yields; loopers, 2 to 3 percent; stinkbugs, 1 to 2 percent; velvetbean caterpillars, 1 to 2 percent; and Mexican bean beetles, 1 percent (*16*). Several foliar insecticides control more than one of these pests. Major insecticides used to control corn earworms include carbaryl, methomyl, methyl parathion, and permethrin, while acephate and chlorpyrifos are used less frequently. Methomyl, permethrin, and acephate are used to control soybean loopers; whereas carbaryl, methomyl, and methyl parathion are used to control stinkbugs. Methomyl, methyl parathion, and permethrin are used for velvetbean caterpillar control.

Several of the soil insecticides are also used as nematicides on corn and soybeans. About 3 to 4 percent of the U.S. corn and soybean acreage is treated each year for nematodes. Carbofuran and terbufos are the most commonly used corn nematicides, while aldicarb, carbofuran, and fenamiphos are the most commonly used soybean nematicides. Terminating nematicide treatments would decrease corn yields less than 1 percent and soybean yields 1 to 2 percent (*16*).

Insecticide and Nematicide Scenarios

The insecticide and nematicide scenarios are classified into three groups, based on target pest and method of application: soil insecticides, foliar insecticides, and nematicides.

Soil Insecticides

I1 — Terbufos and Isofenfos. There are several effective alternatives (carbofuran, chlorpyrifos, disulfoton, ethoprop, fonofos, and phorate) to terbufos and isofenfos, so withdrawing these two soil insecticides will not significantly affect corn or soybean yields. The Corn Belt and Lake States would incur minor yield losses from corn rootworm larvae. Because terbufos and isofenfos are in the middle of the price range for soil insecticides, it was assumed that farmers choose alternatives so that average control costs do not change in a region (table 3).

I2 — Terbufos and Isofenfos, 25-Percent Price Increase for Alternatives. This scenario has the same yield loss assumptions as scenario I1. To account for scarcity, it was assumed that farmers bid up prices for the chemicals in soil insecticides by 25 percent, resulting in a 25-percent corn rootworm control cost increase and minor cost increases for soybeans (table 3).

I3 — All Soil Insecticides. Banning all chemicals in soil insecticides would cause maximum corn yield losses from corn rootworm larvae and other soil insects, and some damage from European cornborers and nematodes. Some corn producers would use alternative controls for cutworms (fenvalerate for chlorpyrifos) and European cornborers (carbaryl, fenvalerate, methomyl, or permethrin for carbofuran or fonofos). Average corn pest control costs would decrease because there would be no treatment for corn rootworm larvae, but cornborer and cutworm control costs would increase slightly. Soybean pest control costs would increase slightly because more expensive alternatives would be needed for some pests (table 3).

Foliar Insecticides

I4 — Permethrin. Banning permethrin would increase soybean yield losses from loopers in Appalachia, the Delta, and the Southeast. Acephate was assumed to be the primary alternative to permethrin on loopers, and its use would increase control costs in those three regions. Equally effective and costly materials are available for corn earworm, velvetbean caterpillar, and Mexican bean beetle control. Since little permethrin is used, no significant yield losses or cost changes occur for corn (table 4).

Table 3 — Average cost and yield changes from banning soil insecticides on corn and soybeans

Crop and region	Scenario					
	I1		I2		I3	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	0	0	0	0.6	11.8	−2.1
Central Plains	0	0	0	1.4	11.3	−4.7
Corn Belt	0.2	0	0.2	1.3	9.1	−4.1
Delta	0	0	0	1.4	0	0
Lake States	.1	0	.1	.8	5.1	−2.7
Mountain States	0	0	0	1.4	11.3	−4.7
Northeast	0	0	0	.8	2.3	−3.1
Northern Plains	0	0	0	1.3	4.1	−4.8
Southeast	0	0	0	2.3	14.5	−9.2
Southern Plains	0	0	0	1.4	11.3	−4.7
Soybeans:						
Appalachia	0	0	0	.1	0	.2
Central Plains	0	0	0	0	0	0
Corn Belt	0	0	0	0	0	0
Delta	0	0	0	.1	0	.2
Lake States	0	0	0	0	0	0
Northeast	0	0	0	.1	0	.1
Northern Plains	0	0	0	0	0	0
Southeast	0	0	0	0	0	.1

I5 — Permethrin, Fenvalerate, and Methomyl. Soybean yield losses from loopers and corn earworms would increase in Appalachia, the Delta, and Southeastern States, and would be greater than losses in scenario I4. Control costs would remain the same (table 4).

I6 — Permethrin, Fenvalerate, and Methomyl, 25-Percent Price Increase for Alternatives. Yield losses would be the same as in scenario I5, but control costs of all foliar pesticides for soybeans would increase by 25 percent (table 4).

I7 — All Foliar Sprays. Corn earworms, velvetbean caterpillars, and stinkbugs cause major soybean losses in Appalachia, the Delta, and Southeastern States. The Corn Belt, Northeast, and Lake States would suffer losses of about 1 percent. Pest control costs would decrease if foliar sprays were no longer applied (table 4).

Nematicides

I8 — All Nematicides. This scenario bans aldicarb, carbofuran, ethoprop, fenamiphos, fensulfothion, and terbufos. Corn rootworm larvae would cause yield losses because carbofuran, ethoprop, and terbufos are used for its control. This scenario assumes maximum nematode damage to corn and soybeans. However, of the 11.2-percent corn yield loss in the Southeast, 7.3 percent would be caused by southern corn rootworms. Corn rootworm losses would occur in no other regions (table 5).

Table 4 — Average cost and yield changes from banning foliar insecticides on soybeans

Region	Scenario					
	I4		I5		I6	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Appalachia	0.1	0.1	1.5	0.1	1.5	0.3
Corn Belt	0	0	0	0	0	.1
Delta	.6	.2	3.2	.2	3.2	.6
Lake States	0	0	0	0	0	.1
Northeast	0	0	0	0	0	.7
Southeast	9.0	.2	16.4	.2	16.4	.9

Table 5 — Average cost and yield changes from banning foliar insecticides or nematicides on corn and soybeans

Crop and region	Scenario					
	I7		I8		I9	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	0	0	1.2	−1.6	1.2	−1.4
Central Plains	0	0	0	0	0	1.4
Corn Belt	0	0	.7	−.9	.7	.2
Lake States	0	0	.1	−.4	.1	.3
Northeast	0	0	0	0	0	.8
Northern Plains	0	0	0	0	0	1.3
Southeast	0	0	11.2	−8.1	11.2	−8.1
Southern Plains	0	0	0	0	0	1.4
Soybeans:						
Appalachia	7.2	−1.8	3.0	−3.3	3.0	−3.3
Corn Belt	.9	−.6	.7	−.4	.7	−.4
Delta	19.5	−2.9	2.8	−1.4	2.8	−1.4
Northeast	1.2	−3.0	.4	−.3	.4	−.3
Southeast	54.3	−4.9	3.4	−1.4	3.4	−1.4

I9 — All Nematicides, 25-Percent Price Increase for Alternative Insecticides. This scenario assumes that the prices of all materials that control corn rootworms and European cornborers increase by 25 percent if all nematicides were removed from the market (table 5).

Effects of the Insecticide and Nematicide Scenarios

After a 5-year ban of all soil insecticides, the net effect would be a $2.2-billion loss, all foliar insecticides would cause about a $700-million loss, and all nematicides would cause about a $200-million loss. Banning a small number of soil or foliar insecticides would have less severe results than would banning all nematicides. Banning all insecticides used for an important corn or soybean pest would have a much greater effect than would banning a few soil or foliar insecticides but leaving some effective alternatives for each pest. In all scenarios, except those which ban terbufos and isofenfos (scenarios I1 and I2), the transfer of income from consumers to producers would far exceed the net effect (tables 6-8).

Because of the magnitude of the predicted yield losses and their concentration in the Southeast and Delta States, potential bans on permethrin or permethrin, fenvalerate, and methomyl could have greater effects than would banning one or two soil insecticides. (There is no guarantee that one could pick any other set of foliar insecticides and achieve this same result.) In either case, the economic effects would be relatively small. Corn prices would not vary by more than $0.04 per bushel, production would not decrease by more than 0.1 percent, and corn returns would not change by more than about $3.00 per acre (after 5 years). Soybean prices would not change by more than $0.33 per bushel and returns would not increase by more than $7.50 per acre (after 5 years). If permethrin, fenvalerate, and methomyl were banned, production may initially decrease by more than 1 percent, but by less than 1 percent after 5 years (tables 6 and 7). Decreases would be small because alternative pesticides are available to control insects and nematodes.

Increasing the prices of alternative insecticides by 25 percent (scenarios I2, I6, and I9) would not significantly affect prices and production. However, corn and soybean producers would bear most of the additional cost. Scenario I2 shows small per-acre losses for corn and soybeans.

Withdrawing all compounds available for soil insects, foliar insects, or nematodes would cause greater effects. Corn returns would increase after 5 years by $51 per acre if all soil insecticides were banned, by $15 if all foliars were banned, and by $7 if all nematicides were banned. If all soil insecticides were banned, corn prices would increase by almost $0.80 per bushel and production would decrease by almost 6 percent. If all foliar insecticides or nematicides were banned, corn prices would increase by $0.20 per bushel or less and production would decrease by about 1 percent or less. Soybean returns would increase by about $21 per acre if soil insecticides were banned, $33 if foliar insecticides were banned, and $9 if all nematicides were banned. If all foliar insecticides were banned, soybean prices would increase by almost $1.50 per bushel and production would decrease by about 2

Table 6 — Economic effects of removing soil insecticides from the market

Effects	Scenario		
	I1	I2	I3
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	46.6	−37.9	3,394.0
Year 5	70.3	−7.2	5,984.8
Consumers' surplus —			
Year 1	−66.5	−56.2	−4,828.1
Year 5	−96.6	−114.8	−8,132.1
Net effect —			
Year 1	−19.9	−94.2	−1,434.1
Year 5	−26.3	−107.6	−2,148.2
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.01	.01	.70
Year 5	.01	.02	.79
Soybeans —			
Year 1	<.01	<.01	.05
Year 5	.01	<.01	.86
Acreage change:	*Million acres*		
Corn —			
Year 2	.03	−.04	1.90
Year 5	.03	*	2.06
Soybeans —			
Year 2	−.01	.03	−1.16
Year 5	<.01	*	−.43
Production change:	*Percent*		
Corn —			
Year 1	−.10	−.10	−8.80
Year 5	−.07	−.10	−6.10
Soybeans —			
Year 1	0	0	0
Year 5	.01	0	−1.20
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	.55	−.66	39.74
Year 5	.65	−.10	51.34
Soybeans —			
Year 1	.02	−.02	1.08
Year 5	.19	−.09	21.28

*Decrease of less than 10,000 acres.

percent after 5 years. Banning all soil insecticides would increase soybean prices by $0.86 per bushel and would decrease production by about 1 percent after 5 years. Banning all nematicides would cause smaller price and production changes for soybeans. Effects on corn of banning foliar insecticides would primarily be a response to changes in soybean yields and returns since foliar insecticides are seldom used on corn. Likewise, effects on soybeans of banning soil insecticides would primarily be a response to changes in corn yields and returns since soil insecticides are seldom used on soybeans (tables 6-8).

Fungicides

Seed treatments are the major fungicide applications for both corn and soybeans. Almost all of the corn seed and a third of the soybean seed are annually treated to control seed rots and seedling blights. If seed were no longer treated, average corn yields would initially decrease by 5 percent and soybean yields by 2 percent (*16*). The major compounds used in seed treatments are captan, carboxin, and thiram, all of which are equally effective in many, but not all, environmental situations.

Table 7 — Economic effects of removing foliar insecticides from the market

Effects	Scenario			
	I4	I5	I6	I7
Welfare effects:	*Million dollars*			
Total crop rent —				
Year 1	296.2	748.4	735.8	3,385.6
Year 5	284.6	704.7	698.6	3,200.1
Consumers' surplus —				
Year 1	−361.9	−913.7	−913.7	−4,168.4
Year 5	−351.7	−868.7	−875.6	−3,877.2
Net effect—				
Year 1	−65.7	−165.3	−177.9	−782.8
Year 5	−67.1	−164.0	−177.0	−677.0
Price change:	*Dollars per bushel*			
Corn—				
Year 1	.01	.02	.02	.07
Year 5	.02	.04	.04	.18
Soybeans —				
Year 1	.22	.55	.55	2.57
Year 5	.13	.33	.33	1.46
Acreage change:	*Million acres*			
Corn —				
Year 2	−.17	−.42	−.42	−1.85
Year 5	−.06	−.14	−.15	−.69
Soybeans —				
Year 2	.27	.71	.69	3.15
Year 5	.19	.49	.49	2.39
Production change:	*Percent*			
Corn —				
Year 1	0	0	0	0
Year 5	−.10	−.20	−.20	−1.20
Soybeans —				
Year 1	−.60	−1.50	−1.50	−6.80
Year 5	−.20	−.05	−.05	−2.00
Change in returns:	*Dollars per acre*			
Corn —				
Year 1	.52	1.32	1.32	6.17
Year 5	1.35	3.27	3.29	14.59
Soybeans —				
Year 1	4.67	11.80	11.58	53.20
Year 5	3.01	7.44	7.32	33.16

Foliar fungicides are applied annually on 5 percent or less of the soybean acreage and on a negligible amount of the corn acreage. Terminating these treatments could cause average soybean yields to decrease by about 2 percent and could cause negligible corn losses (*16*). Foliar treatments to soybeans, primarily benomyl, are applied mostly in the Delta. Other effective fungicides include chlorothalonil, thiabendazole, and thiophanate-methyl.

Fungicide Scenarios

The fungicide scenarios are classified into two groups, based on target pest and timing of application: seed treatments and foliar fungicides.

Table 8 — Economic effects of removing nematicides from the market

Effects	Scenario	
	I8	I9
Welfare effects:	*Million dollars*	
Total crop rent —		
Year 1	1,043.6	982.6
Year 5	1,127.4	1,079.3
Consumers' surplus —		
Year 1	-1,193.7	-1,183.8
Year 5	-1,316.5	-1,324.5
Net effect —		
Year 1	-150.0	-201.2
Year 5	-189.2	-245.2
Price change:	*Dollars per bushel*	
Corn —		
Year 1	.07	.07
Year 5	.09	.09
Soybeans —		
Year 1	.47	.47
Year 5	.35	.34
Acreage change:	*Million acres*	
Corn —		
Year 2	-.11	-1.64
Year 5	.11	.08
Soybeans —		
Year 2	.59	.62
Year 5	.43	.43
Production change:	*Percent*	
Corn —		
Year 1	-.70	-.70
Year 5	-.60	-.60
Soybeans —		
Year 1	-1.20	-1.20
Year 5	-.50	-.50
Change in returns:	*Dollars per acre*	
Corn —		
Year 1	5.54	4.64
Year 5	7.04	6.50
Soybeans —		
Year 1	10.96	10.96
Year 5	8.85	8.61

Seed Treatments

F1 — Captan. Banning captan would only slightly affect yield and cost for corn and soybeans because of thiram's (an effective alternative) availability. Only the Lake States would suffer a 1.3-percent corn yield loss (table 9).

F2 — Captan, 25-Percent Price Increase for Alternatives. This scenario assumes the same yield changes as in scenario F1 but greater cost changes from higher prices for alternative foliar fungicides (table 8).

F3 — All Seed Treatments. This scenario would cause maximum corn and soybean yield losses from seed rots and seedling blights. Corn yield losses as high as 11 percent would occur in the Northeast and Plains States. Pest control costs would decrease because seed would no longer be treated against pests (table 9).

Foliar Fungicides

F4 — Benomyl. Thiophanate-methyl was assumed to be the primary alternative to benomyl. Soybean yield losses approaching 5 percent would occur in the Delta States, but would be negligible elsewhere. Benomyl and thiophanate-methyl are comparably priced so control costs would not increase (table 10).

F5 — Benomyl, 25-Percent Price Increase for Alternatives. This scenario assumes the same yield losses as in scenario F4, but soybean pest control costs would increase in the Corn Belt, Delta, Appalachia, Southeast, and Northeast (table 10).

F6 — All Foliar Fungicides. Soybean yield losses approaching 10 percent would occur in the Delta States, with very small losses in the Corn Belt and Appalachia. Soybean pest control costs would decrease because foliar fungicides would no longer be applied (table 10).

Effects of the Fungicide Scenarios

Projected effects of banning captan or benomyl are small; banning all seed treatments affects U.S. production much more than would banning either of these fungicides. However, banning all foliar fungicides would have slightly greater effects than would banning one of the fungicides. After a 5-year ban of benomyl or captan, the net effect would vary between a $70- to a $100-million loss. Banning all foliar fungicides would cause a net loss of about $130 million, but banning all seed treatments would increase the net loss to $1.2 billion. In all cases, returns to farmers would increase but consumers would bear a cost. The largest increases in farmers' gains and consumers' losses would occur if all seed treatments were banned. As with insecticides, the income transfers from consumers to producers would be greater than the net effects (tables 11 and 12).

Results of banning a single fungicide would be comparable with results of banning a few insecticides. If the prices of alternatives to captan or benomyl increased by 25 percent, additional effects would be negligible, but the returns to farmers growing corn or soybeans would decrease. Banning captan would increase both corn and soybean prices by $0.01 to $0.03 per bushel. Banning benomyl would increase corn prices by $0.02 and soybean prices by $0.16 per bushel. Removing captan from the market would increase the returns to both crops by less than $1.00 per acre. Banning benomyl would increase corn returns by about $1.40 per acre and soybean returns by about $3.50 per acre. Increasing the prices of benomyl alternatives by 25 percent would increase the returns to soybeans by about $3.40 per acre. The results of withdrawing captan or benomyl from the market would be small because effective alternatives are available.

Banning all seed treatments would have smaller effects than would banning all soil insecticides, but greater

Table 9 — Average cost and yield changes from banning seed treatments on corn and soybeans

Crop and region	Scenario					
	F1		F2		F3	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	0	0.37	0	0.70	4.2	−0.95
Central Plains	0	.29	0	.60	11.2	−.93
Corn Belt	0	.41	0	.75	.7	−.91
Delta	0	.19	0	.58	1.2	−1.37
Lake States	1.3	.44	1.3	.77	5.1	−.88
Mountain States	0	.29	0	.60	11.2	−.93
Northeast	0	.37	0	.69	11.3	−.93
Northern Plains	0	.33	0	.81	7.6	−1.59
Southeast	0	.32	0	.65	2.1	−1.02
Southern Plains	0	.29	0	.60	11.2	−.93
Soybeans:						
Appalachia	0	.01	0	.04	1.3	−.08
Central Plains	0	.01	0	.01	2.7	−.03
Corn Belt	0	.02	0	.06	1.0	−.10
Delta	0	.04	0	.09	.5	−.21
Lake States	0	.10	0	.19	.3	−.31
Northeast	0	0	0	0	.6	−.01
Northern Plains	0	.01	0	.01	0	−.02
Southeast	0	0	0	.02	.3	−.05

Table 10 — Average cost and yield changes from banning foliar fungicides on soybeans

Region	Scenario					
	F4		F5		F6	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Appalachia	0	0	0	0.06	0.4	−0.37
Corn Belt	0	0	0	.03	.2	−.19
Delta	4.8	0	4.8	.50	9.7	−2.99
Northeast	0	0	0	.09	0	−1.31
Southeast	0	0	0	.21	0	−.56

effects than would banning all foliar insecticides or all nematicides. Banning all foliars would have an effect only slightly greater than banning benomyl. Banning all seed treatments would cause corn prices to increase by $0.39 per bushel, production to decrease by 3 percent, and returns to increase by $26 per acre (after 5 years). The same ban would cause soybean prices to increase by $0.90 per bushel, production to decrease by about 1 percent, and returns to increase by $21 per acre. Banning all foliar fungicides would cause soybean production to decrease by less than 1 percent and would cause negligible decreases in corn production. Corn prices would increase by about $0.04 per bushel and returns by $3 per acre. Soybean prices would increase by $0.35 per bushel and returns by about $8 per acre.

Herbicides

By using one or more currently available herbicides with tillage and cultural practices, corn and soybean farmers can control a wide variety of weed species. Different herbicide compounds do not control every

Table 11 — Economic effects of removing seed treatments from the market

Effects	Scenario		
	F1	F2	F3
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	46.9	21.9	2,331.8
Year 5	112.2	95.1	3,566.6
Consumers' surplus —			
Year 1	−105.7	−101.6	−3,129.8
Year 5	−183.6	−192.3	−4,717.1
Net effect —			
Year 1	−57.0	−79.8	−780.0
Year 5	−71.4	−96.1	−1,150.6
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.02	.02	.32
Year 5	.02	.02	.39
Soybeans —			
Year 1	<.01	<.01	.61
Year 5	.03	.02	.91
Acreage change:	*Million acres*		
Corn —			
Year 2	.03	.01	.46
Year 5	.02	.02	.70
Soybeans —			
Year 2	−.03	−.02	.19
Year 5	.01	.01	.33
Production change:	*Percent*		
Corn —			
Year 1	*	*	−3.8
Year 5	*	*	−2.9
Soybeans —			
Year 1	0	0	−1.6
Year 5	*	*	−1.3
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	.49	.16	19.28
Year 5	.90	.70	26.33
Soybeans —			
Year 1	**	−.04	13.33
Year 5	.60	.52	21.40

*Decrease of less than 0.01 percent.
**Decrease of less than $0.01 per acre.

Table 12 — Economic effects of removing foliar fungicides from the market

Effects	Scenario		
	F4	F5	F6
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	375.7	368.4	862.4
Year 5	318.1	313.0	729.9
Consumers' surplus —			
Year 1	−454.5	−454.5	−998.4
Year 5	−394.3	−396.4	−857.4
Net effect —			
Year 1	−78.8	−86.1	−136.0
Year 5	−76.2	−83.4	−127.5
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.01	.01	.02
Year 5	.02	.02	.04
Soybeans —			
Year 1	.27	.27	.60
Year 5	.16	.16	.34
Acreage:	*Million acres*		
Corn —			
Year 2	−.21	−.21	−.45
Year 5	−.51	−.51	−.11
Soybeans -			
Year 2	.46	.45	1.01
Year 5	.26	.26	.59
Production change:	*Percent*		
Corn —			
Year 1	0	0	0
Year 5	−.1	−.1	−.2
Soybeans —			
Year 1	−.7	−.7	−1.6
Year 5	−.2	−.2	−.5
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	.65	.65	1.44
Year 5	1.41	1.42	3.01
Soybeans —			
Year 1	5.93	5.81	13.84
Year 5	3.46	3.37	8.15

weed species with equal effectiveness, nor do they perform equally well under various soil and climatic conditions. If an herbicide is removed from the market, farmers who used it will be forced to use other compounds and perhaps change cultural practices (for example, change tillage system or increase cultivation). Situations may result where the control of some weed species is poorer and crop yields decrease despite other compounds and cultural practices being used. This section considers the effects of removing a number of widely used herbicides and chemically related herbicide groups, including acetanilides (alachlor and metolachlor), triazines (atrazine, cyanazine, metribuzin, and simazine), thiocarbamates (butylate+ and EPTC+), and dinitroanilines (oryzalin, pendimethalin, and trifluralin). The individual compounds are alachlor; atrazine; metribuzin; and several postemergence herbicides such as bentazon, linuron, and 2,4-D.

Atrazine is the most widely used triazine on corn. More than 70 percent of the U.S. corn acreage is treated with one or more triazines, with almost 60 percent receiving an atrazine treatment. If all triazines were removed from the market, average U.S. corn yields would decrease by about 10 percent; and corn yields would decrease by 2 to 3 percent if only atrazine were removed from the market (*16*). About 30 to 40 percent of the soybean acreage is annually treated with metribuzin. Average U.S. soybean yields would decrease by 2 to 3 percent if metribuzin were removed from the market.

Approximately 50 percent of the corn acreage is treated with acetanilides; about 30 percent of the acreage is treated with alachlor and the remaining with metolachlor. If acetanilides were removed from the market, U.S. corn yields would decrease by about 6 percent, but yields would decrease by less than 0.1 percent if only alachlor were removed. Acetanilides are used almost as widely on soybeans as on corn, on about 40 percent of the acreage. Alachlor is annually applied to about 30 percent of the soybean acreage. U.S. soybean yields would decrease by about 3 percent if acetanilides were removed from the market and by less than 0.1 percent if alachlor were removed (*16*).

Thiocarbamates are used on about 20 percent of the corn acreage and on 1 percent of the soybean acreage. Most of the thiocarbamate-treated corn acreage receives butylate+, about 16 percent, and the remaining 4 percent receives EPTC+. Corn yields would decrease by about 3 percent without thiocarbamates. Dinitroanilines are applied to 40 to 45 percent of the soybean acreage and to about 1 percent of the corn acreage. Trifluralin, the primary dinitroaniline used on soybeans, is applied to 40 percent of the acreage. However, oryzalin and pendimethalin are also used. Without dinitroanilines, U.S. soybean yields would decrease by about 4 percent (*16*).

Postemergence herbicides are used to control weeds that have started growing in the field. Bentazon and linuron are two important soybean postemergence herbicides, applied to 10 to 15 and 25 percent of the acreage, respectively. U.S. soybean yields would decrease by about 4 percent if bentazon were removed from the market and by about 1 percent if linuron were removed. An important corn postemergence herbicide, 2,4-D, is applied to 10 to 15 percent of the corn acreage. U.S. corn yields would decrease by about 2 percent if 2,4-D were removed from the market. Dicamba, which is not considered further, is used on a comparable corn acreage as 2,4-D and would cause similar losses if removed from the market (*16*).

Herbicide Scenarios

Herbicide regulatory scenarios include both yield and cost changes. The experts did not estimate cost changes but instead identified alternatives including pesticide, tillage, and cultural practices. A cost was then developed for each alternative listed by the experts, and a modified average cost change was estimated for each region. Farmers use many practices; little is known about their choice criteria and even less is known about shifts under restricted choice sets. It was assumed that farmers would generally not use expensive pesticides developed for specialized purposes or older, cheaper alternatives unless they were commonly identified by State experts. The average cost was midway between the high- and low-cost alternatives in the set under consideration. In addition, a change in timing from preemergence or postemergence to preplant incorporated requires an extra pass over the field. For some scenarios, extra cultivations were deemed necessary. An extra pass over the field was assumed to cost $5 per acre (*6*).

Acetanilides

H1 — Alachlor. This scenario assumes that farmers use metolachlor as the alternative herbicide. Average pest control costs would increase slightly because metolachlor is more expensive than alachlor. Corn yield losses approaching 7 percent were assumed for Appalachia if alachlor were removed from the market, while average losses would be less than 1 percent in the Southeast. Soybean yield losses would occur only in the Lake States and would be less than 1 percent (table 13).

H2—All Acetanilides. Depending upon the region and tillage system, farmers may use cyanazine, simazine, butylate+, pendimethalin, amiben, dicamba, linuron, paraquat, or ametryn on corn. Atrazine was not assumed to be an alternative because it is very often mixed with acetanilides. Alternative pest controls for soybeans include trifluralin; pendimethalin; oryzalin; and several postemergence herbicides such as bentazon, acifluorfen, sethoxydim, fluazifop-butyl, metribuzin, and paraquat. If acetanilides were removed from the market, average corn yield losses would approach or exceed 10 percent in Appalachia, the Delta States, the Lake States, and the Northern Plains. Average corn yield losses would exceed 4 percent in all remaining regions except the Southeast. Average soybean yield losses could be approximately 27 percent in the Northeast, 5 percent in the Corn Belt, and 0 to 1 percent in the remaining regions. Average control costs would increase by several dollars per acre for corn and generally less than $1 per acre for soybeans (table 13).

H3 — All Acetanilides, 25-Percent Price Increase for Corn and Soybean Herbicides. This scenario assumes the same losses and alternatives as in scenario H2. Because acetanilides constitute a large portion of the corn and soybean herbicide use, it was assumed that the prices of all herbicides for these crops are bid up 25 percent due to scarcity (table 13).

Triazines

H4 — Atrazine. Atrazine is used only on corn. Alternatives include thiocarbamates, acetanilides, simazine, cyanazine, 2,4-D, dicamba, paraquat, and glyphosate. Removal of atrazine would result in corn yield losses of approximately 15 percent in the Northeast, 7 percent in the Northern Plains, 4 percent in Appalachia, and 2 percent or less in the remaining regions. Control cost increases are greater for banning atrazine than for banning acetanilides (table 14).

H5 — Metribuzin. This triazine is used only on soybeans. Alternatives include acetanilides; vernolate; and a number of postemergence herbicides such as 2,4-DB, bentazon, acifluorfen, chloramben, dyanap, and linuron. An extra cultivation was assumed in the Southeast. If metribuzin were removed from the market, soybean yields would decrease by about 11 percent in the Central Plains, 3 percent in Appalachia and the Delta, and 1 percent or less in the remaining regions. Average control costs would change by less than $1 per acre (table 14).

H6 — All Triazines. For corn, the alternatives are the same as for atrazine, excluding simazine and cyanazine. However, two extra cultivations were assumed for all acreage currently treated with triazines.

Table 13 — Average cost and yield changes from banning acetanilide herbicides on corn and soybeans

Crop and region	Scenario					
	H1		H2		H3	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	6.6	3.76	12.8	3.50	12.8	8.50
Central Plains	0	.40	4.3	1.60	4.3	4.90
Corn Belt	0	.74	4.6	3.50	4.6	7.10
Delta	0	.52	10.9	3.10	10.9	21.20
Lake States	0	.85	9.4	3.20	9.4	6.00
Mountain States	0	.40	4.3	1.60	4.3	4.90
Northeast	0	.56	7.6	2.70	7.6	6.55
Northern Plains	0	.45	8.6	1.80	8.6	4.00
Southeast	.3	.58	.3	2.70	.3	5.95
Southern Plains	0	.40	4.3	1.60	4.3	4.90
Soybeans:						
Appalachia	0	.54	.8	.60	.8	7.30
Central Plains	0	.62	0	.50	0	3.40
Corn Belt	0	.53	4.8	1.65	4.8	6.05
Delta	0	.13	0	.40	0	5.70
Lake States	.1	.43	.4	.40	.4	4.00
Northeast	0	.56	26.8	.90	26.8	6.80
Northern Plains	0	.16	0	.20	0	3.50
Southeast	0	.48	.6	.40	.6	7.20

If all triazines were removed from the market, corn yield losses would be large, exceeding 30 percent in the Northeast, 20 percent in the Delta, 10 percent in the Lake States and Appalachia, and 7 percent in the Corn Belt, Northern Plains, and Southeast. Control cost increases are also high because of the added cultivations. For soybeans, the scenario is the same as for banning metribuzin (table 14).

H7 — All Triazines, 25-Percent Price Increase for All Corn and Soybean Herbicides. This scenario is the same as scenario H6 except that farmers were assumed to bid up the prices of all corn and soybean herbicides due to scarcity (table 15).

Thiocarbamates and Dinitroanilines

H8 — All Thiocarbamates. Butylate+ and EPTC+ are used only on corn. Alternatives include acetanilides, atrazine, cyanazine, pendimethalin, bentazon, ametryn, linuron, paraquat, and glyphosate. One additional cultivation was assumed in Appalachia and the Southeast. If all thiocarbamates were removed from the market, losses would be about 11 percent in Appalachia, 5 percent in the Central and Southern Plains and Mountain regions, and 3 percent in the Corn Belt. Control costs would decrease by several dollars per acre except in the Southeast (table 15).

H9 — All Dinitroanilines. These compounds are used primarily on soybeans. Alternatives include acetanilides, glyphosate, acifluorfen, fluazifop-butyl, and sethoxydim. If all dinitroanalines were removed from the market, soybean yield losses would approach 11 percent in the Central Plains, 8 percent in the Delta, 5 percent in the Corn Belt, and 3 percent in Appalachia and the Lake States. Pest control costs would increase by several dollars per acre (table 15).

Postemergence Herbicides

H10 — Bentazon. This postemergence herbicide is used primarily on soybeans. Alternatives include metribuzin, acifluorfen, linuron, dyanap, and 2,4-DB. If bentazon were removed from the market, soybean yield losses would be about 8 percent in the Delta and Northeast, 5 percent in the Corn Belt, and 2 percent in Appalachia and the Lake States. Control costs would decrease by several dollars per acre (table 16).

H11 — Linuron. This postemergence herbicide is also primarily used on soybeans. Alternatives include metribuzin, bentazon, acifluorfen, chloramben, and 2,4-DB. If linuron were removed from the market, soybean yield losses of 15 percent would occur in the Northeast but would be 2 percent or less in all remaining regions. Pest control costs would decrease slightly in all regions (table 16).

Table 14 — Average cost and yield changes from banning triazine herbicides on corn and soybeans

Crop and region	Scenario					
	H4		H5		H6	
	Yield loss	Cost change	Yield loss	Cost change	Yield loss	Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	4.0	7.10	0	0	15.1	19.40
Central Plains	.7	7.30	0	0	.7	13.00
Corn Belt	1.4	4.10	0	0	8.3	13.40
Delta	1.6	6.90	0	0	20.2	9.80
Lake States	1.4	3.10	0	0	11.3	9.80
Mountain States	.7	7.30	0	0	.7	13.00
Northeast	14.9	6.90	0	0	31.7	18.40
Northern Plains	7.1	.80	0	0	7.1	6.40
Southeast	1.1	6.60	0	0	7.3	16.70
Southern Plains	.7	7.30	0	0	.7	13.00
Soybeans:						
Appalachia	0	0	2.5	.02	2.5	.02
Central Plains	0	0	10.8	.02	10.8	.02
Corn Belt	0	0	.5	.10	.5	.10
Delta	0	0	3.4	−.90	3.4	−.90
Lake States	0	0	.4	.20	.4	.20
Northeast	0	0	0	0	0	0
Northern Plains	0	0	0	.04	0	.04
Southeast	0	0	.9	.16	.9	.16

Table 15 — Average cost and yield changes from banning triazine, thiocarbamate, and dinitroaniline herbicides on corn and soybeans

Crop and region	H7 Yield loss	H7 Cost change	H8 Yield loss	H8 Cost change	H9 Yield loss	H9 Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	15.1	24.40	11.1	−1.00	0	0
Central Plains	.7	16.30	5.3	−1.70	0	0
Corn Belt	8.3	17.00	3.0	−.80	0	0
Delta	20.2	27.90	.1	−1.90	0	0
Lake States	11.3	12.60	.1	−.80	0	0
Mountain States	.7	16.30	5.3	−1.70	0	0
Northeast	31.7	22.15	.6	−.40	0	0
Northern Plains	7.1	8.60	0	−1.60	0	0
Southeast	7.3	19.95	1.4	.30	0	0
Southern Plains	.7	16.30	5.3	−1.70	0	0
Soybeans:						
Appalachia	2.5	6.72	0	0	2.6	0.80
Central Plains	10.8	2.92	0	0	10.8	1.90
Corn Belt	.5	4.50	0	0	4.9	.80
Delta	3.4	6.20	0	0	8.0	1.90
Lake States	.4	3.80	0	0	2.8	1.30
Northeast	0	5.90	0	0	0	0
Northern Plains	0	3.34	0	0	1.9	2.40
Southeast	.9	6.96	0	0	.6	.70

Table 16 — Average cost and yield changes from banning postemergence herbicides on corn and soybeans

Crop and region	H10 Yield loss	H10 Cost change	H11 Yield loss	H11 Cost change	H12 Yield loss	H12 Cost change
	Percent	*Dollars per acre*	*Percent*	*Dollars per acre*	*Percent*	*Dollars per acre*
Corn:						
Appalachia	0	0	0	0	2.8	0.30
Central Plains	0	0	0	0	0	.40
Corn Belt	0	0	0	0	2.0	.30
Delta	0	0	0	0	.9	.20
Lake States	0	0	0	0	.4	.90
Mountain States	0	0	0	0	0	.40
Northeast	0	0	0	0	2.1	.10
Northern Plains	0	0	0	0	8.6	1.40
Southeast	0	0	0	0	0	.70
Southern Plains	0	0	0	0	0	.40
Soybeans:						
Appalachia	2.3	−1.50	1.0	−0.40	0	0
Central Plains	.6	−.40	0	−.07	0	0
Corn Belt	4.9	−1.60	.1	−.20	0	0
Delta	8.0	−2.20	0	−.38	0	0
Lake States	1.8	−.80	.1	−.05	0	0
Northeast	7.6	−.60	15.2	−1.20	0	0
Northern Plains	0	−.90	1.9	−.03	0	0
Southeast	.7	−1.60	.3	−.30	0	0

H12 — 2,4-D. This postemergence herbicide is used primarily on corn. The primary alternative is dicamba, but farmers may also use atrazine or cyanazine in some States. If 2,4-D were removed from the market, corn yield losses would reach almost 9 percent in the Northern Plains; 2 to 3 percent in Appalachia, the Corn Belt, and Northeast; and less than 1 percent in the remaining regions. Control costs would increase slightly in all regions (table 16).

Effects of the Herbicide Scenarios

Banning an entire group of chemically related herbicides would have greater effects on crop production than would banning an individual member (unless the group consists of only one compound). The efficacy of yield of the alternatives is critical in determining effects of banning any herbicide or group of herbicides. Of all the groups examined, banning triazines would have the greatest net effects after 5 years, a $3.3- to $3.8-billion loss, followed by acetanilides with a $2.1- to $2.7-billion loss. Banning thiocarbamates and dinitroanilines would have much smaller net effects, $740-million and $630-million losses, respectively. However, banning some individual herbicides would have greater welfare effects than banning some groups. For example, banning atrazine would cause net losses of $780 million, less than the triazines of which it is a member but greater than thiocarbamates or dinitroanilines. Among the other individual herbicides examined, banning alachlor would cause a $149-million loss, while banning postemergence herbicides (bentazon, linuron, and 2,4-D) would cause losses from $27 million for linuron to $416 million for bentazon (tables 17-20).

In all scenarios presented, farmers would gain and consumers would lose; the income transfers would be much greater than the net loss. The increases in total crop rent in year 5 would vary from $27 million for banning linuron to $5.4 billion for banning all triazines, if herbicide prices did not increase. Consumer losses would vary from $209 million to $8.9 billion for the same scenarios. If herbicide prices increase, there would be little increase in net effects (losses), but farmers would largely bear the additional cost.

Of all the herbicide groups examined, banning triazines would have the greatest effect on corn variables, followed by acetanilides, thiocarbamates, and dinitroanilines. This ranking coincides with the ranking of corn acreage treated with each class of herbicide. Since dinitroanilines are used on such a small share of the corn acreage, the effects of banning this class would largely be a response to soybean yield and cost changes. Corn prices would increase after 5 years from a minimum of $0.10 per bushel for banning dinitroanilines to a maximum of $0.85 for banning triazines. Banning triazines would cause the maximum corn production decrease, 7 percent. Corn production would decrease less than 1 percent if dinitroanilines were banned. Returns to corn would increase an average of $40 per acre if triazines were banned, $30 if acetanilides were banned, $19 if thiocarbamates were banned, and $9 if dinitroanilines were banned.

Among the individual herbicides, banning atrazine would affect corn most, followed by 2,4-D, bentazon, alachlor, and linuron. This ordering does not coincide with the order of corn acreage treated. Very little bentazon and linuron are applied to corn, while less corn acreage is treated with 2,4-D than alachlor. Effects of banning alachlor would be less than banning 2,4-D because alternatives to 2,4-D are less effective. Banning bentazon would cause a relatively large soybean yield loss and a large corn price response. Banning linuron would not significantly affect corn. The increase in corn prices would vary from $0.20 per bushel for banning atrazine to $0.03 for banning alachlor. Banning atrazine would cause corn production to decrease 2 percent while banning alachlor would cause a negligible decrease in production. Banning atrazine, 2,4-D, or bentazon would increase corn returns about $8 per acre, while banning alachlor would increase returns by less than $2.00.

For soybeans, banning acetanilides would have the greatest effect of all the herbicide groups, followed by dinitroanilines, triazines, and thiocarbamates. Banning all acetanilides would increase soybean prices by $1.40 to $1.50 per bushel (depending upon whether herbicide prices are assumed to increase), decrease production by 2 to 3 percent, and increase returns by $30 per acre. Banning dinitroanilines or all triazines would similarly affect soybeans: prices would increase by $1.00 to $1.20 per bushel, production would decrease by 2 percent, and returns would increase by about $25 per acre. Since thiocarbamates are used very little on soybeans, the effects to soybeans are a response to corn yield and cost changes. Prices would increase by about $0.30 per bushel and returns by $8.00 per acre, while production would decrease by less than 1 percent.

Of the individual herbicides examined, banning bentazon would have the greatest effect on soybeans, comparable with banning dinitroanilines or triazines: prices would increase more than $1.00 per bushel, production would decrease by 2 percent, and returns would increase by about $24 per acre. Following bentazon in descending magnitude are bans on metribuzin, atrazine, 2,4-D, linuron, and alachlor. In all these scenarios, soybean prices would increase less than $0.35 per bushel, production would decrease less than 0.5 percent, and returns would increase less than $8 per acre. Neither atrazine nor 2,4-D are used on soybeans, so the soybean effects would be in response to changes in corn yields and costs. Alachlor and metribuzin are much more widely used on soybeans than is bentazon, so the large effects of banning bentazon would be due to relatively poor performance of its alternatives.

Table 17 — Economic effects of removing acetanilide herbicides from the market

Effects	Scenario		
	H1	H2	H3
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	63.6	3,458.5	2,950.1
Year 5	186.2	4,935.0	4,622.2
Consumers' surplus —			
Year 1	−187.6	−5,072.3	−5,101.9
Year 5	−335.0	−7,059.6	−7,270.3
Net effect —			
Year 1	−124.0	−1,613.8	−2,151.8
Year 5	−148.8	−2,124.6	−2,648.1
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.03	.48	.48
Year 5	.03	.57	.59
Soybeans —			
Year 1	<.01	1.23	1.23
Year 5	.05	1.39	1.47
Acreage change:	*Million acres*		
Corn —			
Year 2	.07	.49	.44
Year 5	.06	.98	.88
Soybeans —			
Year 2	−.09	.92	.70
Year 5	.02	.91	.82
Production change:	*Percent*		
Corn —			
Year 1	−.3	−5.7	−5.7
Year 5	−.2	−4.3	−4.4
Soybeans —			
Year 1	*	−3.2	−3.2
Year 5	*	−2.0	−3.0
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	.87	24.17	20.68
Year 5	1.38	34.13	31.83
Soybeans —			
Year 1	−.34	25.23	20.48
Year 5	.86	30.59	28.04

*Decrease of less than 0.01 percent.

Conclusion

Results of the scenarios imply that society will bear a cost if any of the corn or soybean pesticides examined were removed from the market because of reduced production efficiency resulting from lower yields or higher production costs. Consumers, some farmers, and industries between the farm gate and consumers will ultimately bear the costs of such regulations.

Table 18 — Economic effects of removing triazine herbicides from the market

Effects	Scenario		
	H4	H5	H6
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	459.9	749.0	2,909.4
Year 5	1,126.5	694.3	5,411.1
Consumers' surplus —			
Year 1	−1,067.7	−904.5	−5,488.7
Year 5	−1,906.4	−855.4	−8,761.2
Net effect —			
Year 1	−607.8	−155.5	−2,579.2
Year 5	−779.9	−161.1	−3,350.1
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.16	.01	.69
Year 5	.19	.04	.85
Soybeans —			
Year 1	.01	.54	.58
Year 5	.20	.34	1.04
Acreage change:	*Million acres*		
Corn —			
Year 2	.20	−.34	.77
Year 5	.31	−.12	1.35
Soybeans —			
Year 2	−.19	.68	−.07
Year 5	.10	.52	.13
Production change:	*Percent*		
Corn —			
Year 1	−2.0	0	−8.5
Year 5	−1.5	−.2	−6.5
Soybeans —			
Year 1	0	−1.4	−1.4
Year 5	−.3	−.5	−1.5
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	4.43	1.31	23.06
Year 5	8.38	2.85	40.01
Soybeans —			
Year 1	.26	11.82	12.91
Year 5	4.84	7.73	24.88

Of all the scenarios examined, banning triazines, acetanilides, all soil insecticides, or all seed treatments would generate the largest price and welfare effects. Banning all foliar insecticides, thiocarbamates, dinitroanilines, atrazine, or bentazon would cause relatively moderate aggregate effects compared with the other scenarios examined. Among the pest groups, banning all nematicides or foliar fungicides would have relatively small aggregate effects. Except for atrazine and bentazon, banning any of the individual compounds (or a few insecticides) examined would have only minor aggregate effects. However, individual growers could suffer substantial losses in yield and income.

Banning all pesticides used to control a certain pest would have greater aggregate effects than would banning one or a few pesticides used to control that pest (unless these are the only alternatives). Banning an entire herbicide group would have greater effects than would banning one member of that group. However, banning some individual compounds could have greater effects than would banning some herbicide groups or all compounds used for some pest problems. For example, banning atrazine would have smaller effects than would banning all triazines, but a greater effect than would banning all thiocarbamates, dinitroanilines, foliar insecticides, nematicides, or any other herbicide examined. Also, banning bentazon or 2,4-D

Table 19 — Economic effects of removing triazine, thiocarbamate, and dinitroaniline herbicides from the market

Effects	Scenario		
	H7	H8	H9
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	2,496.5	1,276.7	2,148.5
Year 5	5,157.2	2,150.1	2,246.8
Consumers' surplus —			
Year 1	−5,458.3	−1,787.1	−3,011.9
Year 5	−8,922.8	−2,890.2	−2,880.8
Net effect —			
Year 1	−2,961.8	−510.4	−650.0
Year 5	−3,765.6	−740.1	−633.9
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.69	.25	.05
Year 5	.86	.27	.10
Soybeans —			
Year 1	.58	.02	1.83
Year 5	1.16	.32	1.22
Acreage change:	*Million acres*		
Corn —			
Year 2	.77	.75	−.96
Year 5	1.31	.78	−.35
Soybeans —			
Year 2	−.30	−.46	2.40
Year 5	.05	−.15	1.91
Production change:	*Percent*		
Corn —			
Year 1	−8.5	−3.2	0
Year 5	−6.6	−2.1	−.6
Soybeans —			
Year 1	−1.4	0	−4.9
Year 5	−1.6	−.4	−1.7
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	20.99	15.09	4.42
Year 5	38.51	18.48	8.57
Soybeans —			
Year 1	8.17	.41	36.83
Year 5	22.02	8.01	25.49

Table 20 — Economic effects of removing postemergence herbicides from the market

Effects	Scenario		
	H10	H11	H12
Welfare effects:	*Million dollars*		
Total crop rent —			
Year 1	2,331.1	198.5	563.8
Year 5	2,095.0	182.7	944.0
Consumers' surplus —			
Year 1	−2,783.0	−211.7	−854.2
Year 5	−2,510.7	−209.2	−384.6
Net effect —			
Year 1	−451.9	−22.2	−290.4
Year 5	−415.7	−26.5	−384.6
Price change:	*Dollars per bushel*		
Corn —			
Year 1	.05	<.01	.12
Year 5	.09	.01	.13
Soybeans —			
Year 1	1.69	.12	.01
Year 5	1.05	.08	.12
Acreage change:	*Million acres*		
Corn —			
Year 2	−.94	−.09	.28
Year 5	−.30	−.03	.31
Soybeans —			
Year 2	2.52	.17	−.17
Year 5	1.81	.12	−.06
Production change:	*Percent*		
Corn —			
Year 1	0	0	−1.5
Year 5	−.6	*	−1.0
Soybeans —			
Year 1	−4.9	−.3	0
Year 5	−1.7	*	−.2
Change in returns:	*Dollars per acre*		
Corn —			
Year 1	4.07	.30	6.52
Year 5	7.65	.77	8.24
Soybeans —			
Year 1	36.79	3.01	.20
Year 5	24.20	2.00	3.11

*Decrease of less than 0.1 percent.

would have greater effects than would banning all nematicides or foliar fungicides.

In all scenarios, the prices of corn and soybeans increased while production decreased, regardless of whether one or both crops were directly affected by the regulation to remove the pesticide from the market. The market moderates the decreases in the production of crops directly affected by the regulations by encouraging farmers to plant more acreage to those crops in response to higher prices. As a result, the prices, production, and acreage of other crops would also be affected. While sorghum, wheat, and cotton were not discussed, the prices and returns to those crops generally increase in response to removing corn or soybean pesticides from the market.

As a result of the price increases, farmers gained financially in most scenarios, while consumers always suffered a financial loss. Consumers not only bore the brunt of the cost of the regulation, but the higher prices they paid increased farm income. The returns to crops treated with regulated pesticides almost always increased more than the returns to other crops. However, farmers suffering increased crop losses due to the removal of a pesticide may suffer a financial loss even though farmers as a whole gained.

The only scenario under which corn and soybean growers suffered financial losses was the banning of terbufos and isofenfos, assuming a 25-percent cost increase for alternative pesticides (scenario I2). The bans on alachlor and captan (scenarios H1, F1, F2) produced the only other cases where average soybean returns decreased and then only for 1 year. Note that the set of scenarios examined was not exhaustive, so regulations on other pesticides could cause financial losses for corn and soybean farmers. Scenarios which cause financial losses to corn and soybean farmers assumed very small average yield losses and increases in production costs. However, the income to corn and soybeans, as well as all crops, increased in situations where large yield losses and cost increases occurred. In such cases, the revenue increases resulting from price increases under inelastic demands for alternative crops outweighed the cost increases, causing profits to increase.

The exclusion of farm programs from TECHSIM may result in overestimates of increases in farm prices after removing pesticides from the market. Releases from the large corn inventories could dampen price increases, so the income transfer from consumers to producers and the farm income-enhancing aspects of removing pesticides from the market could be overestimated.

The general trends of this report agree with those of Burton and of Taylor and Frohberg: a net social loss would occur such that producers gain and consumers lose. This report's finding that aggregate effects would be relatively small if individual compounds are withdrawn but much greater if entire herbicide groups or all alternatives for a pest problem are withdrawn also agrees with Burton's findings. (Taylor and Frohberg did not examine comparable scenarios.) However, Burton generally found herbicide regulations to have smaller effects on prices and production. A comparison of costs and yield losses does not seem to explain this discrepancy. While there were disagreements between regions, no general trend developed in the cost- and yield-change assumptions to explain why this report predicts somewhat greater effects than Burton's study. The models would likely be a source of differences. Burton's model covered a much larger portion of the agricultural economy, including livestock markets and the availability of labor, and therefore might have allowed for more input and final product substitution than TECHSIM, causing effects to be lower. In addition, demands might be more inelastic in TECHSIM, resulting in greater price and production changes than predicted by Burton's model.

Implications

With several exceptions, the results show that banning any single corn or soybean pesticide will have only minor aggregate economic effects. However, banning several alternatives used for a pest problem can result in very large impacts. Therefore, this report shows the interdependence among regulatory decisions. Canceling a pesticide reduces the alternatives available to combat a particular pest problem, and thus the number of alternatives available in the event of any future cancellation. The outcome of a pesticide regulatory decision will influence the effects of future regulatory decisions.

The acetanilides illustrate the interdependence among decisions. The results show the net effect of banning alachlor, assuming metolachlor is available, to be about a $149-million loss (table 17). Banning metolachlor, assuming alachlor is available, would not be greater than a $149-million net loss. The experts in every region claimed that alachlor was equal to or slightly superior to metolachlor in controlling weeds. In addition, metolachlor is somewhat more expensive than alachlor. However, banning both acetanilides would have a net effect of a $2.12-billion loss. Banning metolachlor, assuming alachlor has already been banned, would cause a net loss of $1.98 billion. There would be similar effects to other welfare indicators, prices, and production. Thus, a decision to remove alachlor from the market would substantially affect the outcome of banning metolachlor later. If a decision were made to remove metolachlor first, it would substantially affect the economic results of a decision to ban alachlor.

The calculated safety, health risks, or environmental hazards that chemicals pose are also interdependent. This interdependence occurs because risk measures depend on the intensity of health problems that a chemical causes (for example, acute toxicity, carcinogenicity, or teratogenicity) as well as probable exposure. Thus, an acutely toxic chemical that currently shows only minor use could be judged as not very hazardous or risky. Another chemical with much more extensive use, and hence higher exposure to users and the general population, could be considered far more dangerous to the environment even if the intensity of its health risks were less. Removing the allegedly hazardous chemical from the market could induce farmers to use a chemical that was formerly out of favor. Use of an acutely toxic material could balloon. A regulation could replace exposure to one chemical with exposure to a far more toxic substance. The risks that a chemical poses depends on previous regulations because regulations will influence use. To precisely estimate both the benefits and risks of continued chemical use, one must forecast changes in use. The *Pesticide Assessment of Field Corn and Soybeans* shows that these changes could be significant (*10-15*).

This interdependence among regulatory decisions reveals a weakness in the pesticide-by-pesticide approach traditionally used in pesticide regulatory analyses and decisionmaking. In addition, EPA has not randomly selected pesticides for review. Insecticides were selected for review in the early and mid-seventies. The order in which they were reviewed appeared to follow use patterns, with the most heavily used compounds examined first. Reviews of the major fungicides followed in the late seventies. Some herbicides and fumigants are currently under examination.

Such an approach may reduce the number of alternatives available to control a crop pest over time, resulting in substantial effects from future regulatory decisions. Decisions on pesticides that are substitutable in farm production have been, and continue to be, closely sequenced. The benefits derived from continued use of a given chemical may vary radically, depending on prior decisions in the sequence. A major problem emerges if a pesticide examined late in the sequence turns out to have higher health, safety, or environmental risks than did the pesticides previously examined. The economic effects of banning such a pesticide would be much greater than if it were banned earlier in the sequence. Given the new risk and benefit information, a decision to ban the pesticide under current consideration and keep one or more previously banned pesticides on the market might result in lower exposure risk and economic loss. Determining the sequence in which pesticides are to be examined could substantially influence the risks and economic effects ultimately borne by society.

This problem is compounded if several materials used for the same pest problem are reviewed in a very short time. Examining each material independently ignores the fact that each material is an alternative for the others. A decision to remove one or more from the market would invalidate all other analyses which did not account for the potential decision.

It is important to structure the pesticide regulatory process to consider the interdependence of regulatory decisions in a cost-effective manner. The *Pesticide Assessment of Field Corn and Soybeans* shows that an approach using expert estimates of cost and yield changes can be structured to show the economic implications of such interdependence (*10-15*). Such an approach could be used in at least two ways. First, estimates of crop yield and production cost changes for acreage without chemical pest controls will show the "worst case" loss of benefits. Such a situation could help target groups of chemicals for a more intensive and systematic assessment of risks and benefits. Second, the approach could be used to assess the economic implications of a variety of regulatory options. Such an approach could assess the risks and benefits of the same options. The *Pesticide Assessment of Field Corn and Soybeans* should be a guide for developing such an approach and should also indicate pitfalls to avoid (*10-15*).

If a pesticide-by-pesticide approach is to be retained, the sequence of decisions becomes critical if the interdependency problem is to be minimized. If a quick, inexpensive method for ranking relative risk were available, then one should draft a preliminary ranking of the relative safety and environmental risks of each chemical in the group to be assessed, beginning with the chemical of highest relative risk and descending in order of risk. Such sequencing of decisions would reduce the probability that a highly risky chemical would be one of the later chemicals examined after less risky alternatives were removed from the market. Preliminary estimates of economic losses without chemical groups or all chemicals used for a target pest would make the procedure more efficient. Efforts to determine the sequence of decisions by relative risk would focus on those chemicals where regulatory decisions could cause the greatest economic losses.

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